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APPLICATION FOR UNITED STATES LETTERS PATENT

for

MODULAR LINER HANGER

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BACKGROUND OF THE INVENTION

This invention relates generally to setting liner hangers during well completion or maintenance operations. In particular, the invention is directed to a liner hanger in which the cones of the liner hanger are non-integral to the barrel and attached by mechanical means without welding.

Generally, in a producing well, casing (lengths of steel pipe joined together) runs from the surface to a specified depth in the wellbore. The casing generally has a large diameter. It is installed and cemented in place to seal off drilling and circulating fluids from the borehole and prevent commingling of well fluids, and to prevent the walls of the borehole from caving. The casing string is generally hung from a hanger on the surface.

A liner is a length of casing that is hung inside existing casing. Unlike the casing string, the liner generally does not extend to the surface, but is anchored, suspended, and supported by a liner hanger that is installed near the bottom of the casing in which the liner is suspended, or near the location where the liner string is desired to isolate problems such as from other zones such as lost circulation or high pressure. The liner also provides capital savings in reducing the cost of the steel pipe needed since it does not run to the top of the well.

A liner hanger holds the liner in place once the liner is in the desired location in the well, and carries the weight of the liner after it is hung off. Mechanical or hydraulic slips on the hanger hold the liner in place by gripping the inside wall of the casing in which the liner is suspended. Hangers may be set hydraulically by creating pressure in the hanger, activating hydraulic pistons that move the slips against the casing. During the running process the slips are retained in a retracted position. Once the liner is in the desired position, the slips are driven across the cones by the activation mechanism, which may be mechanical or hydraulic, thereby increasing the diameter of the slips and forcing the teeth on the outer surface into the casing. Liner hangers generally include one or more sets of cones and slips.

The cones are wedge-shaped sections on the liner hanger's outer wall. Generally in the past, the cones have been integral to the barrel of the liner hanger. For example, in a common type of prior art liner hanger the barrel is made of two piece construction, as shown in FIGS. 1A and 1B. A lower portion of the barrel is threaded onto an upper

1 portion and acts as a hydraulic cylinder. The entire assembly contains a longitudinal
2 throughbore that allows for the passage of fluids during the running process. The slips
3 and cones are slotted to allow the passage of fluid in the annulus around the liner hanger
4 during the running in/removal or cementing processes.

5 With the hydraulic version, when the liner hanger is in the desired position, the
6 operator creates an increased pressure, generally by dropping a ball or dart into a ball seat
7 or other receptacle in a landing collar below the liner hanger. At a particular increased
8 pressure a setting piston moves upward to an extended position. The setting piston drives
9 a setting sleeve, connected by one or more slip arms to the slips. This drives the slips,
10 which expand out over the wedge-shaped cone pads until fully gripping the inside of the
11 casing. Downward motion transfers the full liner weight through the cones and slips into
12 the supporting casing.

13 Alternatively, the hanger can be mechanically set. In one such hanger, the work
14 string attached to the liner hanger is rotated. Rotation may be right-hand set or left hand
15 set depending on the desired embodiment. The rotation causes a J-Cage mechanism in
16 contact with the casing to disengage a lug from the short leg of the J-Cage and allows the
17 slips to align with the cones. Downward motion then allows the slips to expand over the
18 cones and grip the casing's inner wall, transferring the weight of the liner to the
19 supporting casing.

20 A disadvantage of such prior art liner hangers is that they must be constructed
21 using a very thick-walled steel tube stock, for example a six inch inner diameter might
22 require an eight inch outer diameter, in order for the wall to have sufficient thickness in
23 the area of the cones and the cylinder once the steel tube is machined inside and out.
24 This creates expense in the material, in the machining time, and in the construction.

25 Other liner hangers have been constructed with a single-piece mandrel or barrel.
26 In this case, the cylinder or J-Cage is connected to the barrel using mechanical means
27 such as set screws, wirelocks, or welding. The cones are generally integral to the barrel
28 as described above, but in some prior art embodiments the cones may have been welded
29 to the barrel, which adds cost and time to the production. In addition, because of the
30 complexity and cost of the tool construction, it is impractical to create stock items.

1 Welding the cones or the cylinder to the barrel or casing mandrel requires
2 multiple welds. These welds add time and expense to the manufacture of the liner
3 hanger. More importantly, welding can affect the metallurgy of the barrel, making the
4 welded area subject to attack, for example by corrosive well fluids. As such, welding to
5 the barrel or to a casing mandrel is at minimum undesirable, and may be prohibited under
6 certain industry standard regulations. As such, mechanical connections are preferable.

7 The disadvantages of two-piece liner hanger, and the single-piece welded liner
8 hanger, are overcome by the present invention.

9 SUMMARY OF THE INVENTION

10 It is an aspect of the current invention that a liner hanger, whether mechanical or
11 hydraulic, may be constructed in a modular fashion. The cones are attached to a barrel or
12 mandrel in a manner that is mechanical, does not require welding, and is highly resistant
13 to axial movement. It is a further aspect of the invention that the mechanical connection
14 is made using non-adhesive components combined in such a manner that they will resist
15 the high temperatures, high pressures, and corrosive fluids and gases that may be
16 encountered in the well.

17 In the embodiment described herein, the present invention provides a high-
18 strength non-welded mechanical connection between the cones of a liner hanger and a
19 barrel or mandrel. As such, the liner hanger can be built using standard stock casing,
20 reducing the over-all expense. In general, the liner hanger includes at least one set of
21 cones and slips.

22 One or more grooves or channels are cut in an outer wall of the barrel. In
23 preferred embodiments, the groove or channel is sufficiently shallow to avoid
24 significantly thinning the wall thickness of the barrel. The inside surface of the cones
25 contains at least one partially or fully annular slot or groove oriented to correspond with
26 the groove(s) in the outer wall of the casing mandrel.

27 At least one lock is situated in the corresponding slot and the groove. The lock
28 engages the flanks of the slot and groove sufficiently to resist shears loads applied by the
29 weight of the liner that is hung off, and axial movement during running in the hanger. In
30 a preferred embodiment, the lock is one or more wires, although other mechanical
31 locking devices may be installed to provide the same function.

1 The cones of the liner hanger, as well as the cylinder and slips, can be easily
2 installed on, or removed from the barrel. A standard size barrel can accommodate cones
3 and slips of various sizes as needed for the characteristics of a particular well, the piston
4 or J-Cage area needed, and the weight of the particular length of liner to be hung off the
5 liner hanger. As such, the system of the current invention provides a liner hanger that is
6 constructed of separately built and stored modules, and one that uses mechanical non-
7 welded connections.

8 **BRIEF DESCRIPTION OF THE DRAWINGS**

9 FIG. 1A is an elevation of an upper portion of a prior art liner hanger with a two-
10 piece barrel;

11 FIG. 1B is an elevation of a lower portion of a prior art liner hanger with a two-
12 piece barrel;

13 FIG. 2A is a partial sectional elevation of an upper portion of a hydraulically
14 actuated modular liner hanger;

15 FIG. 2B is a partial sectional elevation of a lower upper portion of a hydraulically
16 actuated modular liner hanger;

17 FIG. 3 is a partial sectional elevation of cones connected to the liner hanger;

18 FIG. 4 is a second partial sectional elevation of cones connected to the liner
19 hanger, shown at a different radial location;

20 FIG. 5 is a cross section of the hydraulically actuated modular liner hanger shown
21 in FIG. 2;

22 FIG. 6 is a partial sectional elevation of a hydraulic actuation mechanism of the
23 modular liner hanger;

24 FIG. 7A is a sectional elevation of an upper portion of a mechanically actuated
25 modular liner hanger; and

26 FIG. 7B is a sectional elevation of a lower portion of a mechanically actuated
27 modular liner hanger.
28

DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

In FIGS. 2A and 2B, an upper and lower portion of a hydraulic-set modular liner hanger 10 are shown. Partial figures are meant to show certain aspects of embodiments of the invention, and are not necessarily continuous.

The modular liner hanger comprises a body or barrel 20, which may also be called a mandrel or casing mandrel, or a liner hanger body. Barrel 20 is generally cylindrical and contains a generally cylindrical internal through bore 22. The barrel may be made out of standard size and standard material casing that is well known in the oilfield practice, or can be made out of specialty pipe sizes or materials. At one end the barrel 20 may contain a tapered and threaded portion 24 for connection to a running string, liner packer, and/or liner setting tools (not shown).

A first set of cones or cone pads 50 is journaled about the barrel 20. Cones 50 are separately machined pieces, and can be constructed of various materials and in various sizes as desired for a particular application. Cones 50 may include two or more cone pads spaced around the circumference; three are shown in the embodiment in the figures herein.

It is a particular aspect of the current invention to provide a modular constructed liner hanger wherein the cones and cylinders are mechanically joined to the barrel in a manner that restricts both axial movement and rotation between the cones and cylinder relative to the barrel. For this reason, prior liner hangers have generally been constructed with the cones integral or welded to the casing mandrel, and the cylinder constructed of a separate barrel section with a threaded connection. The present invention provides a one-piece construction and avoids welding, or reduces the total number of welds.

In one embodiment of the current invention, as shown in FIGS. 2A, 3, and 4, one or more grooves, or a series of radial grooves 26, are cut in the external wall of the barrel 20. Grooves 26 need not be deeply cut into the outside diameter of the barrel 20, and could be little more than indentations, aligned with a series of one or more corresponding annular grooves 52 in the inner wall of the cones 50. Each annular groove 52 is connected to a lateral bore 54 between the groove and the external surface of the cones 50. Referring now to FIGS. 3 and 5, cones 50 also contain a series of concave portions 56 that allow the passage of fluid. Concave portions 56 may alternatively be a series of

1 axial slots, bores, or other means for allowing flowby of a sufficient volume of fluid. In
2 other embodiments, cone pads 50 may be a single cone or may be multiple disjointed
3 cones individually installed.

4 As shown in FIGS. 2A and 3, with the cones 50 journaled about the barrel 20,
5 and the grooves or indents 26 and 52 aligned, a wire or series of wires 60 can be disposed
6 in the grooves 26 and 52. Wires 60 can be installed through the lateral bores 54, cut to
7 appropriate lengths, and the opening of the lateral bores 54 closed if desired.

8 Wires 60 bear on the flanks of grooves 26 and 52 to resist axial movement of the
9 cones 50 relative to the barrel 20. In a preferred embodiment, the yield point of wires 60
10 will be greater than the yield point of the barrel 20 and the cones 50.

11 In alternate embodiments, grooves 26 and 50 could be single helical grooves, and
12 a single wire 60 could be threaded into the helical grooves. In addition, the grooves
13 could be full or partial channels, keyways, or other passageways. Wires 60 could be
14 replaced by a series of ball bearings sized for the grooves or other passageways, roller-
15 type bearings, or keys.

16 A keyway 28 is machined into the outer wall of barrel 20. Key 58 is installed in a
17 the keyway and a corresponding slot in the cones 50 to resist relative rotation and to keep
18 the cones properly aligned. In an alternate embodiment, the cones may not be keyed to
19 the barrel, thus allowing relative rotation.

20 Referring again to FIG. 2A, journaled below the cones 50 are a corresponding
21 first set of slips 70. Slips 70 contain a serrated portion 72. The first set of slips 70 is
22 connected to a first end of one or more slip arms 80 by screws 74, or by other known
23 fastening means.

24 Slip arm 80 extends from the first set of slips 70 to a hydraulic setting mechanism,
25 or to the second set of slips 100 located lower on the barrel 20. The slip arms 80 transfer
26 the initial setting force from the hydraulic setting mechanism. Although two sets of slips
27 are shown, in other embodiments there is only one set of slips, or there may be three or
28 more. Such variations are determined based on the required liner length, hanging
29 capacity, and well conditions, and/or to minimize stress in the supporting casing. The
30 slip arms may be radially offset, as in the embodiment shown.

1 A slip arm support ring 82 may be installed between the barrel 20 and the slip arm
2 80 to stiffen the slip arm 80 as may be necessary based on the arrangement of, and
3 distance between, cones 50 and 90. The second set of cones 90 may be radially offset
4 from the first set of cones 50.

5 Similar to the attachment of cones 50 to the barrel 20, in the embodiment shown,
6 grooves 30 are cut in the external wall of the barrel 20. Grooves 30 are aligned with a
7 second series of one or more corresponding annular grooves 92 in the inner wall of the
8 second set of cones 90. Each groove 92 may be connected to a lateral bore (not shown
9 but which are similar to bore 54) between the groove 92 and the surface of the cones 90.
10 Cones 90 are journaled about the barrel 20, and the grooves 30 and 92 are aligned so that
11 a wire or series of wires 62 can be disposed in the grooves 30 and 92. Wires 62 may
12 have a higher yield point relative to the barrel 20 and the cones 90. Grooves 30 and 92
13 could be single helical grooves with a single wire 62. The grooves could be full or partial
14 channels, keyways, or other passageways. Wires 62 could be replaced by a series of ball
15 bearings sized for the grooves or other passageways, roller-type bearings, or wires or
16 keys.

17 A second keyway (not shown) may be machined into the outer wall of barrel 20,
18 and a second key may be installed in the keyway and a mating slot in the cones 90 to
19 resist relative rotation and to keep the cones 90 properly aligned.

20 Second set of slips 100 may be radially offset from the first set of slips 70, but is
21 aligned with the second set of cone pads 90. The second set of slips 100 also contains a
22 serrated portion 102. The serrated portions 72 and 102 of the slips 70 and 100 are
23 sufficiently hardened to allow setting into the particular grade of casing in the well.

24 The second set of slips 100 is coupled to a second slip arm 110 by any mechanical
25 means, for example, the screws 112 shown. Slip arms 80 and 100 are coupled to a setting
26 mechanism 120. In one embodiment, setting mechanism 120 includes limit ring 135.
27 Slip arms 80 and 110 are coupled to the setting sleeve 136.

28 As shown in FIGS. 2B and 6, a cylinder 132 is also journaled about the barrel 20.
29 Cylinder 132 has a counterbore area that, together with the outer wall of barrel 20, piston
30 138 and associated seals 139, seal 133, and gage ring 140 create a chamber 144. A port
31 36 in barrel 20 allows the passage of fluid from the throughbore 22 to chamber 144.

1 Thus when the hydraulic liner hanger 10 has reached its desired position, a ball or dart is
2 dropped and lands in a seat or receptacle resulting in a pressure increase as additional
3 fluid is pumped down the string. The cylinder 132 may be shear pinned to actuate at a
4 predetermined pressure value. At the desired pressure, the piston 138 moves upward,
5 driving the setting sleeve 136 upward. Setting sleeve 136 is slotted such that the slots
6 137 allow travel upward and downward, but set screws 134 located in the slots 137
7 restrain rotation of the setting sleeve 136 relative to the barrel 20. With the piston 138
8 travelling upward, the force is transferred from the setting sleeve 136 to the slip arms 80
9 and 110. This causes slips 70 and 100 to come in contact with the cones 50 and 90, and
10 to be expanded outward until serrated edges 72 and 102 and in gripping relation with the
11 casing. In conjunction with shoulder 146, limit ring 135 provides a backup to set screws
12 134 in restraining the maximum travel distance for the slip arms 80 and 110.

13 Gage ring 140 provides the base for the chamber 144. Barrel 20 contains a third
14 set of grooves 34 cut in the external wall of the barrel 20. Grooves 34 are aligned with
15 another series of one or more corresponding annular grooves 142 in the inner wall of the
16 gage ring 140. Each groove 142 may be connected to a lateral bore. Gage ring 140 is
17 journaled about the barrel 20 such that the grooves 34 and 142 are aligned and a third
18 wire or series of wires 64 can be disposed in the grooves 34 and 142. Wires 64 may have
19 a higher yield point relative to the barrel 20 and the gage ring 140. Grooves 34 and 142
20 could be single helical grooves with a single wire 64. The grooves could be full or partial
21 channels, keyways, or other passageways. Wires 64 could be replaced by a series of ball
22 bearings sized for the grooves or other passageways, roller-type bearings, or wires.

23 Setting mechanism 120 and/or cylinder 132 may have an area of larger outside
24 diameter to protect the slips 70 and 100 and slip arms 80 and 110 during running of the
25 liner hanger 10. In addition, at the distal end of barrel 20 there may be a tapered and
26 threaded portion 38 for connection to a liner packer, and/or liner setting tools (not
27 shown).

28 As can be seen, the cones 50 and 90, and the gage ring 140 of setting mechanism
29 120 are connected to the barrel or casing mandrel 20 by means of one or more wirelocks,
30 or similar mechanical type connections, without the need for welding. It can also be seen
31 that the body of the liner hanger 20 has a generally uniform wall thickness in the portion

1 of the liner hanger where the cones 50 and 90 and the gage ring 140 are journaled and
2 coupled, thus the tool need not be manufactured from heavy wall pipe.

3 In an embodiment shown in FIGS. 7A and 7B, one possible version of a
4 mechanical set liner hanger in accordance with the current invention is illustrated.
5 Mechanical set liner hanger 150, is comprised of barrel 220, one or more set of cone pads
6 250 and 290, and slips 270 and 300 associated with the cone pads 250 and 290. The
7 cones 250 and 290 are attached to the barrel 220 using mechanical non-welded
8 connections, which can be a wirelock mechanism as detailed in FIGS. 3 and 4. The
9 cones 250 and 290 contain one or more grooves 252 and 292 that are aligned with
10 channels or grooves 226 and 230 in the outer wall of the barrel 220. One or more wires
11 260 and 262, bearings, or other mechanical apparatus sufficiently stress resistant, are
12 installed in the mating grooves 226 and 252, and 230 and 292, in the cones and barrel.
13 Locked in this manner, the cones 250 and 290 are held in a manner that resists axial loads
14 and restricts axial movement of the cones 250 and 290 relative to the barrel 220. Cones
15 250 and 290 may be keyed to the barrel 220 using keys 258 and 296 installed in the barrel
16 keyways 228 and 232, to resist rotation of the cones relative to the barrel.

17 The slips 270 and 300 in mechanical set liner hanger 150 are driven by J-Cage
18 360. The J-Cage 360 contains a J-shaped slot 362. A lug 364 is positioned within the J-
19 shaped slot 362. During the running of the mechanical set liner hanger 150, the lug 364
20 is held against the short leg of the slot 362 because of the drag forces on the J-Cage 360
21 which is in contact with the casing (not shown). When the hanger is in the desired
22 location in the well, the mechanical hanger 150 is set by lifting the work string to release
23 the lug 364 from the short leg of the slot 362. The mechanical hanger 150 is then rotated,
24 to the right for right-hand set, and to the left if left-hand set, to shift the lug to the long leg
25 of the J-shaped slot 362 and to align the slips 270 and 300 with the cones 250 and 290.
26 With the cones 250 and 290 and slips 270 and 300 aligned, downward motion of the
27 work string brings the cones 250 and 290 into contact with the slips 270 and 300,
28 expanding the serrated edges of the slips 270 and 300 into the casing wall. The weight of
29 the liner is transferred through the slips 270 and 300 into the surrounding casing to
30 support the liner.

1 While the apparatus and methods of this invention have been described in terms
2 of preferred and illustrative embodiments, it will be apparent to those of skill in the art
3 that variations may be applied without departing from the concept and scope of the
4 invention. All such similar substitutes and modifications apparent to those skilled in the
5 art are deemed to be within the scope and concept of the invention.

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